

Expansion of the Distribution Range and Pollinators of *Canavalia rosea* (Fabaceae) in the Ryukyu Archipelago, Japan

SHUN-ICHI MATSUMURA^{1*}, YOICHI TATEISHI², JUN YOKOYAMA³ and MASAYUKI MAKI³

¹Biological Institute, Graduate School of Science, Tohoku University, Sendai, Miyagi 980-8578, Japan; ²College of Education, University of the Ryukyus, Nishihara, Okinawa 903-0129, Japan; ³Division of Ecology & Evolutionary Biology, Graduate School of Life Sciences, Tohoku University, Sendai, Miyagi 980-8578, Japan

New localities of *Canavalia rosea* were found on Okinawa and in the Amami Islands of the Ryukyu Archipelago. The locality on Amami-Oshima marks the northern-most limit of the species in Asia and extends its range approximately 490 km northeastward. At its newly discovered locations, *C. rosea* is pollinated by female leaf cutter bees and bears fruit. We suspect that the presence of three closely related species of *Canavalia* with flowers morphologically similar to those of *C. rosea* is probably one of the main reasons for the visitation by leaf cutter bees to *C. rosea* in the Ryukyu Archipelago. The female bees exhibited two patterns of behavior during flower visitations and effectively pollinated the flowers of *C. rosea* only when collecting both pollen and nectar. Pollinators of *C. rosea* have been reported as being anthopholid bees elsewhere, but are leaf cutter bees in the Ryukyu Archipelago.

Key words: *Canavalia rosea*, leaf cutter bees, new distribution, pollinators, Ryukyu Archipelago

The Ryukyus are a subtropical archipelago of continental islands situated between Taiwan and the Japanese mainland. The vegetation is basically evergreen forests of the Sino-Japanese Floristic Region (Takhtajan 1986). Numerous plants with their center of distribution in the tropics have representative in the archipelago. *Canavalia rosea* (Sw.) DC. (Papilionoideae, Fabaceae), is a typical plant of tropical seashores (Sauer 1964) with fruit adapted to dispersal by ocean currents (Ridley 1930). Previously it was known in Japan from only the Yaeyama and the Miyako Islands in the southern Ryukyu Archipelago (Walker 1976, Shimabuku

1993, Hatusima & Amano 1994). In this paper we report new localities of *C. rosea* from the northern Ryukyus and observations on reproductions in the species in the newly discovered habitats.

New distribution records

Between 1995 and 2003 we found *Canavalia rosea* at seven new localities (Yonaguni, Kume, Ikei, Okinawa, Okinoerabu, and in the Amami-Oshima Islands) in the Ryukyu Archipelago (Table 1, Fig. 1). These discoveries extend the distribution range approximately 490 km northeastward, with the Amami-Oshima Island populations at 28°16'N,

*present address :Graduate School of Engineering and Science, University of the Ryukyus, Senbaru, Nishihara, Okinawa 903-0213, Japan

TABLE 1. New localities of *Canavalia rosea* and sites where drift seeds were collected in the Ryukyu Archipelago. Stage of plants is as follows; FL, flowering; FR, fruiting; SL, seedlings; DS, drift seeds. For number of new localities, see figure 1.

Island	Locality	Stages	Specimen ¹	Observation years
Takara	Ohgomori	DS	S. M. DS-2464	2002
Kikai	Ikeji	DS	S. M. DS-2701	2002
Amami-Oshima	Uken Village, Ashiken-Ikegachi (1)	FL, FR	Y. T. & T. K. s.n.	1999
	Uken Village, Funakoshi	DS	Y. T. DS-796	1999
	Kasari Town, Domori Beach	DS	S. M. DS-887	2001
	Naze City, Chinaze	DS	Y. T & T. Y. DS-1559	1998
	Naze City, Arira	DS	S. M. DS-2752	2002
Uke	Ikeji	DS	S. M. DS-2566	2002
Okinoerabu	Eastern coast of Cape Hanzaki (2)	FL, FR	S. M. 990001	1999*
	Naikina Beach (3)	FL, FR	S. M. 990002	1999*
	Ujiji Beach	DS	S. M. DS-851	2001
Okinawa	Kunigami Village, Hentona (4)	FL, FR, SL	Y. T. & al. 43517	1996-2003
	Nakijin Village, Nagahama	DS	Y. T & T. Y. DS-797	1999
Ie-jima	-	DS	Y. T DS-1561	1995
Sesoko	Western beach	DS	Y. T & al. DS-1562	1996
Ikei	Eastern beach (5)	FL, FR	S. M. 990003	1999*
Kume	Shimajiri (6)	FL, FR	S. M. s.n.	1999-2001**
Miyako	Bora Port, Cape Higashi-henna	DS	S. M. DS-800	1999
	Ditto	DS	S. M. DS-2042	2001
	W beach, Cape Higashi-henna	DS, FL, FR	S. M. DS-801	1999
Ishigaki	Cape Hirakubo	DS, FL, FR	S. M. DS-1571	1996
	Akaishi	DS	S. M. DS-1563	1996
	Inoda	DS	S. M. DS-1568, 1569	1996
	Yoshihara	DS	S. M. DS-802	1999
	Todoroki River	DS, FL, FR	S. M. DS-803, 1172	1996, 1997 †
	Shiraho	DS, FL, FR	S. M. DS-1564 - 1566	1994, 1996 †
Yonaguni	Higawa Beach (7)	FL, FR	S. M. s.n.	1995*

¹ Abbreviations of collector names are as follows: Y. T. = Y. Tateishi, T. K. = T. Kurosawa, T. Y. = T. Yamashiro, S. M. = S. Matsumura.

* These populations were absent in 1996 on Yonaguni Island, and in 2001 on Okinoerabu and Ikei islands.

** We observed fruiting plants only in 1999.

† Records are years of observation of drift seeds. Although we observed flowering and fruiting plants at a few localities on Ishigaki Island, years were not recorded because the plants were common.

129°15'E being the northernmost limit of the species in Asia. The populations on Yonaguni, Ikei, and Okinoerabu islands have been lost since we discovered them. At all newly discovered sites *C. rosea* was a trailing plant on beaches next to the sea. The plants bore fruits at all sites. We observed fruits in the Hentona population on Okinawa Island every year from 1996 to 2003 and in the Shimajiri population on Kume Island in 1999. Seedlings at

the Okinawa site were evidence of regeneration. We did not find fruits in the population on Kume Island in either 2000 or 2001, but we saw fruits and a pollinator in 1999. We presume that the plants we found originated from seeds carried by oceanic currents. We collected drift seeds of *C. rosea* on the coasts of Okinoerabu in the Amami-Oshima islands and at other places (Table 1, Fig. 1).

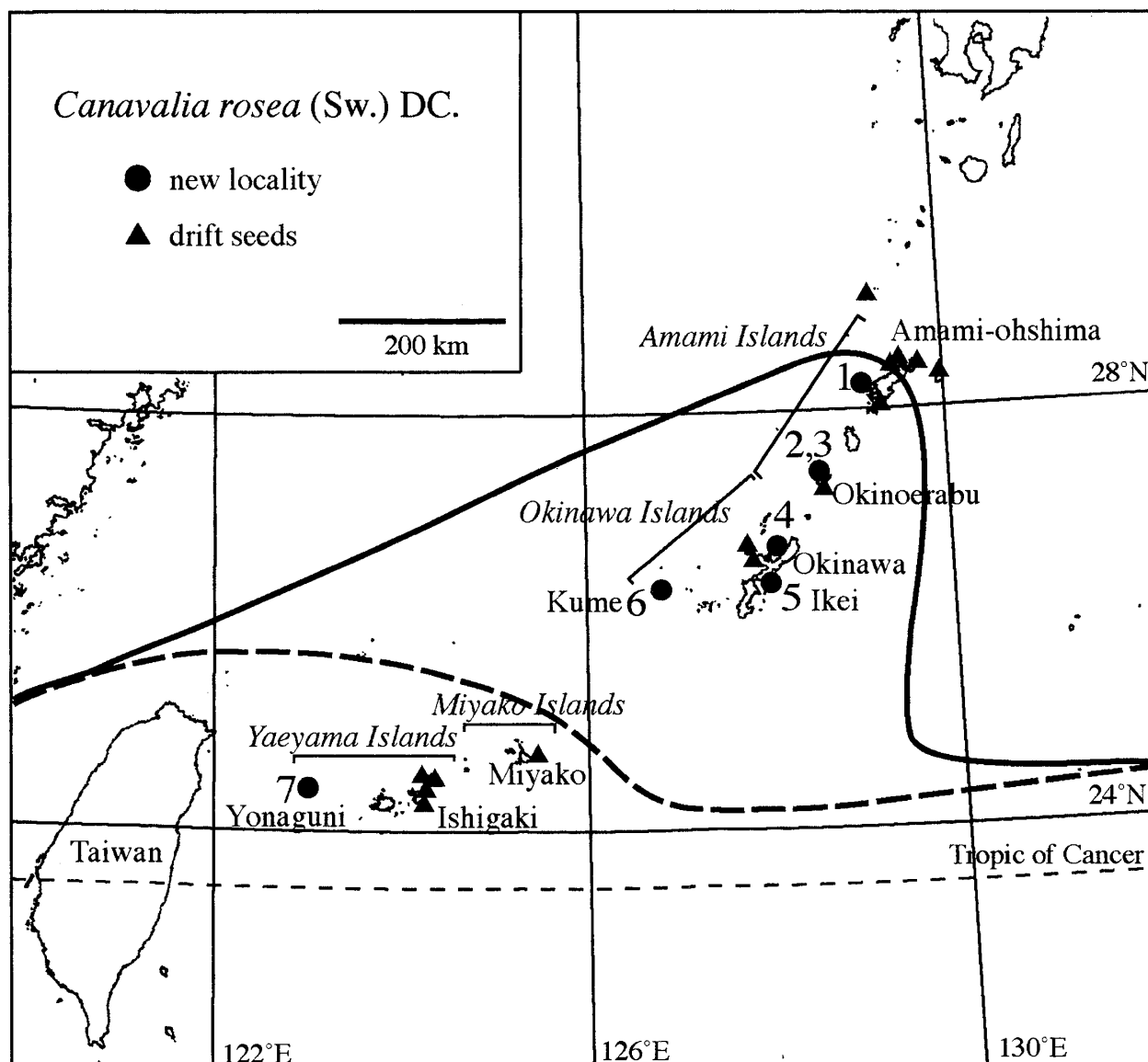


FIG. 1. New localities of *Canavalia rosea* and sites where drift seeds were collected in the Ryukyu Archipelago. Broken and thin lines show previous and new northern limits of distribution, respectively. For number of new localities, see Table 1.

Reproduction in the new localities

Although there were relatively few individuals at each site, fruits were well-developed at all of the sites we discovered. Because *Canavalia rosea* is self-incompatible (Gross 1993) and because the stigma and anthers are hidden by the two keel petals, the flower has to be pollinated by a vector that has the ability to force open the petals (Faegri & van der Pijl 1979). We observed that *C. rosea* was pollinated by females of the leaf cutter bees *Megachile okinawana* Yasumatsu & Hirashima at

three sites and by *Chalicodoma monticola* (Smith) at one site (Table 2, Fig. 2).

In addition to *Canavalia rosea*, two other species of *Canavalia*, *C. lineata* (Thunb.) DC. and *C. cathartica* Thouars, are also distributed in the Ryukyu Archipelago. Both are closely related to *C. rosea* (Sauer 1964), and are mainly pollinated by leaf cutter bees and carpenter bees (Kato 2000, S. Matsumura *et al.* unpublished data). Except for the carpenter bees, the pollinators of *C. lineata* and *C. cathartica* are the same as those of *C. rosea*.

TABLE 2. Flower visitors of *Canavalia rosea* in the Ryukyu Archipelago and on Lanyu Island, Taiwan. Numbers of flower visitors are shown in parenthesis.

Island	Flower visitors			Date
	<i>Megachile bicolor</i> group	Megachilidae (leaf cutter bee) other <i>Megachile</i>	Anthophoridae <i>Chalicodoma</i> <i>Xylocopa</i>	
Amami-				
Oshima				No observation
Okinoerabu	<i>M. okinawana</i> (1 ♀)			Oct.99
Okinawa	<i>M. okinawana</i> (3 < ♀)		<i>C. monticola</i> (2 ♀)	20.Jun.97
	<i>M. okinawana</i> (1 < ♀)		<i>C. monticola</i> (3 < ♀)	27.Jul.97
Ikei				No observation*
Kume	<i>M. okinawana</i> (1 ♀)			1.Sep.99
Miyako	<i>M. yaeyamaensis</i> (3 < ♀, 1 < ♂)	<i>M. igniscopata</i> (1 ♀)		24, 25 June 1999
Ishigaki	<i>M. yaeyamaensis</i> (5 < ♀, 3 < ♂)			17.Aug.99
Lanyu			<i>X. ruficeps</i> (1 ♀)	10.Sep.98

* Matsumura observed the holes on the standard, which the leaf cutter bees made by chewing with the mandibles, in 27 Aug.1999

The morphological features of flowers of the three species of *Canavalia* are quite similar elsewhere (Sauer 1964, Stirton 1977, Gottsberger 1988), as they are in the Ryukyus. The presence of the three closely related species with similar flowers is probably one of the main reasons for visitations to *C. rosea* by leaf cutter bees in spite their small population sizes.

Behavior of pollinators

The female leaf cutter exhibit two patterns of behavior when they visit flowers of *Canavalia rosea*. To collect nectar, they alight on the standard petal and press their head to the keel/wing petal complex while sucking nectar. In doing this, they do not contact the stigma, because their body is at a distance from the keel/wing petal complex. When they collect both pollen and nectar the bees alight on the standard first and then quickly turn their bodies

upside down. They remain inverted while biting the basal part of the standard with their mandibles and while gripping the wing petals. They then force open the keel/wing petal complex and actively collect pollen with their legs. The pollen adheres mainly to the scopae and legs and is later deposited on the stigma of other flowers (Fig. 2). They therefore act as pollinators only when collecting both pollen and nectar.

Male leaf cutter bees do not effect pollination in spite of their frequent flower visits; they collect only nectar and never come in contact with the stigma. Other flower visitors were also observed; *Ceratina okinawana* Matsumura & Uchida (Anthophoridae), *Campsomeriella annulata* Fabricius (Scoliidae), and a few species of Lepidoptera. We doubt their effectiveness as pollinators, however, because *Ce. okinawana* appeared only to rob the pollen and the other visitors never came in contact



FIG. 2. Female leaf cutter bee, *Megachile okinawana*, visiting flowers of *Canavalia rosea* at Hentona, Okinawa Island. Bee pushes down keel/wing petal complex with legs while biting standard. Ventral surface of abdomen of bee covered by yellow pollen in contact with pistil (white arrow). Legs of bee in contact with anthers near abdomen. Two bite marks on basal part of standard (black arrow). Scale bar = 1.5 cm.

with the stigma. Those flower visitors are nectar and/or pollen robbers.

Other anthophorid bees have been reported previously as pollinators of *Canavalia rosea*, for example, *Xylocopa frontalis* (Olivier), *X. orthognaspis* Moure, *Centris fluviatilis* Friese, *Centris* sp., and *Acanthopus palmatus* (Olivier) in Brazil (Gottsberger *et al.* 1988), *X. violacea* L. in South Africa (Scott Elliot 1891) and *X. latipes* (Drury) and *X. confusa* Pérez in Indonesia (Gross 1993). Additionally, we observed *C. rosea* being pollinated by *X. ruficeps* Friese on Lanyu Island southeast of Taiwan (Table 2). *Canavalia rosea* was mostly pollinated by *Megachile yaeyamaensis* Yasumatsu & Hirashima, and rarely by *M. igniscopata* Cockerell in the southern Ryukyu Islands (Table 1). Both *M. okinawana* and *M. yaeyamensis* are endemic to

the Ryukyu Archipelago (Yamane *et al.* 1999), and belong to the *M. bicolor* group (Yasumatsu & Hirashima 1964).

Pollination by leaf cutter bees is rare in the genus *Canavalia*. Only Stirton (1977) reported that *C. virosa* (Roxb.) Wight & Arn. was pollinated by the leaf cutter bee, *Megachile combusta* Smith, in South Africa, with the main pollinator being a carpenter bee, *Xylocopa flavorufa* De Greer. *Megachile combusta* was an opportunist and did not always succeed in pollinating the flowers of *C. virosa*. Our observations indicate that the pollinators of *C. rosea* have switched from being anthophorid bees to leaf cutter bees in the Ryukyu Archipelago, even though three endemic species of *Xylocopa* (Anthophoridae) occur there (Yamane *et al.* 1999). We do not know why carpenter bees do not visit the flowers of *C.*

rosea. It may be that leaf cutter bees are relatively more predominant in the Ryukyu Archipelago and their abundance may reduce flower visitation by carpenter bees through resource competition.

We are grateful to two anonymous reviewers, Drs. H. Ohashi, T. Nemoto, M. Kato, J. Okazaki, A. Naiki, M. Hotta, T. Kajita, T. Kurosawa, Y. Iwokawa and Mrs. N. Nikaidoh for providing useful advice, and Dr. C. H. Stirton for sending us reprints of his papers. We also thank Dr. T. Yamashiro, Ms. K. Kurima, Y. Mukoh, M. Kamizato and E. Tamaki for their help in the field and in the laboratory.

References

- Faegri, K. & L. van der Pijl. 1979. The Principles of Pollination Ecology. 3rd edition. Pergamon Press, Oxford.
- Gottsberger, G., J. M. F. Camargo & I. Silberbauer-Gottsberger. 1988. A bee-pollinated tropical community: the beach dune vegetation of Ilha de São Luís, Maranhão, Brazil. Bot. Jahrb. Syst. 109: 469-500.
- Gross, C. L. 1993. The reproductive ecology of *Canavalia rosea* (Fabaceae) on Anak Krakatau, Indonesia. Austral. J. Bot. 41: 591-599.
- Hatusima, S. & T. Amano. 1994. Flora of the Ryukyus, South of Amami Island. 2nd edition. The Biological Society of Okinawa, Okinawa. (In Japanese)
- Kato, M. 2000. Anthophilous insect community and plant-insect interactions on Amami Islands in the Ryukyu Archipelago, Japan. Contr. Biol. Lab. Kyoto Univ. 29: 157-252.
- Ridley, H. N. 1930. The Dispersal of Plants throughout the World. L. Reeve & Co., Ltd., Kent.
- Sauer, J. 1964. Revision of *Canavalia*. Brittonia 16: 106-181.
- Scott Elliot, G. F. 1891. Notes on the fertilisation of South African and Madagascar flowering plants. Ann. Bot. 5: 333-405.
- Shimabuku, K. 1993. Distribution of leguminous plants in the Ryukyus. Island Studies in Okinawa 11: 1-13. (In Japanese)
- Stirton, C. H. 1977. The pollination of *Canavalia virosa* by xylocopid and megachilid bees. Bothalia 12: 225-227.
- Takhtajan A. 1986. Floristic Regions of the World. University of California Press, Los Angeles.
- Walker, E. H. 1976. Flora of Okinawa and the Southern Ryukyu Islands. Smithsonian Institution Press, Washington, D.C.
- Yamane, S., S. Ikudome & M. Terayama. 1999. Identification Guide to the Aculeata of the Nansei Islands, Japan. Hokkaido University Press, Sapporo.
- Yasumatsu, K. & Y. Hirashima. 1964. Red-haired leaf-cutter bees of the group of *Megachile bicolor* from Japan, the Ryukyus and Formosa. Kontyu 32: 175-187.

Received June 16, 2004 ; accepted September 28, 2004